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A Model to Calculate Effectiveness of a Submarine-Launched Nuclear ASW Weapon

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PKPLOT: A Model to Calculate Effectiveness of a Submarine-Launched Nuclear ASW Weapon

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Introduction

LLNL's Navy Tactical Applications Group (NTAG) has produced a computer model to calculate the probability of kill of a submarine-launched nuclear ASW standoff-weapon. Because of the uncertainties associated with target position and motion and with weapon delivery, this is a problem appropriately treated statistically. The code is a Monte Carlo simulation which follows the engagement from localization through optional evasive maneuvers of the target to attack and damage assessment.

For a given scenario (weapon characteristics, target characteristics, firing platform depth and hardness, etc.) the code produces a table and ultimately a plot of Pk as a function of range.

Description

Description of a simplified scenario may prove useful. After localizing the target and determining his course and speed, the attacking sub chooses an aimpoint, either the last known position of the target or the predicted intercept position, and fires a weapon. If the submarine commander has options for weapons of different yields, the weapon and corresponding yield chosen is the maximum that allows the firing submarine to maintain a safe standoff distance. The weapon is launched from the submarine, rises to the surface, where a rocket motor ignites, flies to its aimpoint, splashes down, sinks to its yield-dependent burst depth, and detonates.

It is possible that the target submarine has been alerted at weapon launch, broach, or splash (or, if the attacking sub has used active sonar to localize the target, by a sonar ping) and has chosen to evade. Evasion can consist of any combination of changes in speed (accelerate, slow, or maintain speed), depth (surface, go deep, or maintain depth), and heading (turn broadside to attacking sub, turn away from splash, turn some fixed angle, or maintain heading). The functions used for modeling evasion in this code are simplistic representations of acceleration, depth change, and turning.

When detonation occurs, the target submarine may be a substantial distance away from the burst for several reasons: localization is statistically described, as shown in figure 1, and may have been poor; the target has moved since its position was last determined, perhaps in an evasive fashion, shown in figure 2; there are delivery errors associated with getting a weapon to its aimpoint. A lethal radius for the weapon is calculated on the basis of weapon yield, depth of burst, depth of target when detonation occurs, and target hardness. If the target submarine was within the lethal radius of the weapon at detonation, the encounter is scored as a kill.

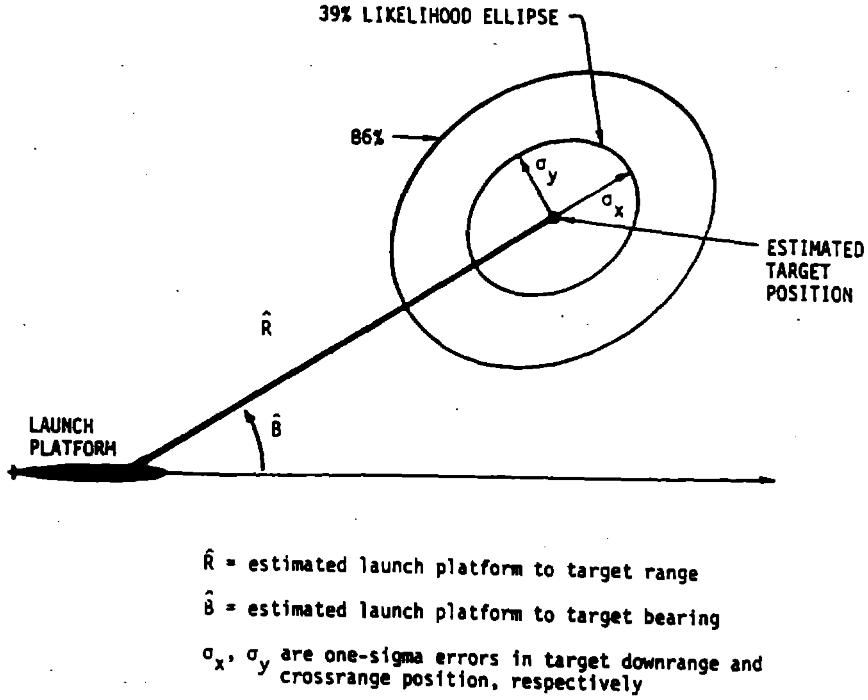

Figure 1. Target Likelihood Ellipses

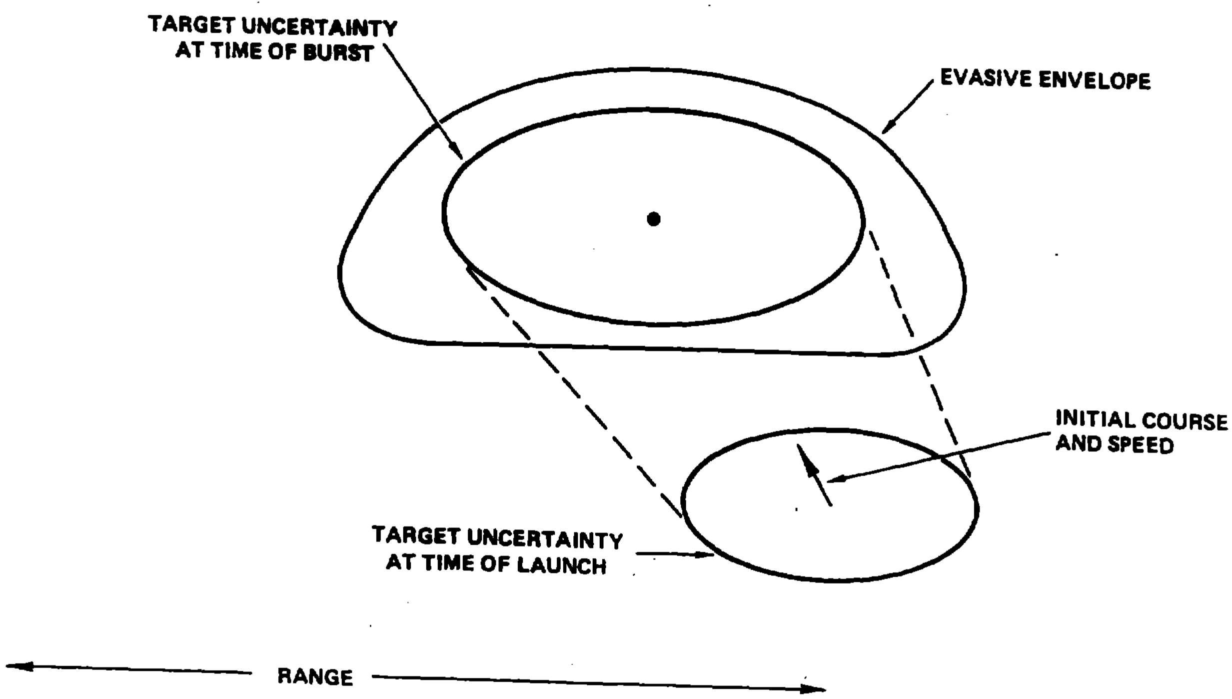

Figure 2. Target Position Uncertainty Time Evolution

Because of the statistical nature of this engagement (there are uncertainties associated with determination of localization and motion, with weapon delivery, with the effect of wind on weapon delivery, and with target aspect at the time of launch), the entire engagement is repeated about a thousand times to provide a valid average Pk at each engagement range.

Table 1 lists the parameters input to the model. Those marked with an asterisk are chosen independently from a normal distribution with an input standard deviation for each Monte Carlo iteration.

Table 1
PKPLOT inputs

<u>Targeting</u>

Range to target
Down-range localization error (1σ)*
Cross-range localization error (1σ)*
Speed error (1σ)*
Course error (1σ)*
Whether aimpoint is last known position (LKP) or predicted intercept (PI)

<u>Weapon specifications</u>

Number of weapons
If salvo, geometric pattern intended
Yields
Depth of burst for each yield
Delivery errors (CEP) (errors due to wind are also included)*
Rise speed
Flight speed
Sink speed
Reliability

<u>Target description</u>

Initial speed
Initial depth
Initial aspect (can be input, or can be a Monte Carlo variable)*

<u>Target vulnerability to nuclear attack</u>

Submarine radius
Maximum working depth
Whether lethality is calculated by excess impulse or by peak translational velocity (PTV)
Lethal peak translational velocity
Dependence of lethal PTV on sub orientation relative to burst
Lethal excess impulse

Target evasion

How target is alerted (weapon launch, broach, splash, or active sonar ping from attacking submarine)
How target chooses to evade:
Depth: can surface, go deep, or maintain
Speed: can accelerate, slow, or maintain
Turn: can broadside to alerting signal, away from splash, execute a fixed turn, or maintain heading
Minimum and maximum sub speeds
Maximum deceleration
Parameters describing acceleration (dependent on target class)
Turn rate
Pitch rate
Maximum climb angle
Reaction time to commence evasion

Attacking submarine

Maximum safe PTV
Submarine radius
Launch depth
Time to process active sonar ping

Other

Number of Monte Carlo iterations
Whether output is to show Pk for each yield or for maximum safe yield at each range

*Monte Carlo variable

Utility

This model provides us with the necessary understanding for making critical design decisions for a nuclear standoff weapon, especially regarding the choice of appropriate values for such weapon characteristics as yield, burst depth, speed, and delivery accuracy. The model also provides a way to understand the relative importance of these parameters in the study of issues such as the following:

--A weapon of a higher yield has a larger lethal radius, but is not safe for the firing sub to use at short ranges. Does the increased lethality make up for the loss of short-range capability?

--Increasing the burst depth generally increases the lethal radius, but it also increases time-to-target, allowing the target more time for evasion. At what burst depth is effectiveness maximized?

--If delivery speed can be increased at the expense of delivery accuracy, is it a worthwhile tradeoff?

Sensitivity studies also allow us to quantify the effects of technological improvements--for example, what is the effect of improving our localization capability, or of delivering the weapon faster, or more quietly (so that the target is less likely to be alerted)? Several such studies have been done at LLNL.

Also, once the basic weapon parameters are determined, we can draw conclusions about the effectiveness of different targeting and firing tactics as a function of target submarine evasive maneuvers, allowing for more effective (or more covert) use.